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SOURCE Elektrichestvo, No 12, 1949, pp 6-9.THE SMALL-SIZE MEM-50 ELECTRON MICROSCOPE

Cand Tech Sci N. G. Sushkin
 Engr P. V. Zaytsev
 Engr O. N. Rybakov, Moscow
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The useful magnification of an electron microscope is equal to 100,000 times. This does not mean that it is necessary to build electron microscopes with such colossal magnification. An image with considerably less magnification can be obtained in an electron microscope and then enlarged again by ordinary photography. The resolving power can be preserved if the electronic and light magnifications are correctly chosen. The magnitude of the latter is determined by the quality of the photographic material used. Ordinary photographic plates allow the resolving power of the image to be increased four or five times without loss. Consequently, if an image magnified 25,000 times is obtained in the electron microscope and then enlarged another four times photographically, a total magnification of 100,000 is obtained.

Because of technical considerations, when working with an electron microscope, it is more advantageous to obtain the least possible magnification in the instrument itself and then enlarge it photographically. The less the magnification, the greater the brightness of the image with the same electron beam loading of the specimen. The brightness of the image decreases in proportion to the square of the magnification if the current density remains unchanged. Lack of brightness makes focusing difficult and necessitates prolonged photographic exposures. It is undesirable to increase the brightness by increasing the density of the electron current as the specimen becomes heated and deformed. Moreover, the field of vision becomes limited at large magnifications.

It is simpler to take a portion of the object at low magnification and then select an interesting place on the negative for enlarging, or else enlarge the whole negative, thereby obtaining a large photograph. For example,

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the dimensions of the EM-100 microscope plate are 6.5 x 9 cm. By photographing an object magnified 20,000 times it is possible, by fivefold optical magnification of the negative image obtained in the microscope, to attain a total magnification of 100,000, i.e., to obtain a 30 x 40-cm print. To investigate the same area at the same magnification, obtained directly from the microscope, it would have been necessary to take 25 photographs.

Industrial electron microscopes usually give a maximum magnification of 20,000-30,000 times. But in practice even this magnification is superfluous in many cases. In the first place, a resolving power of 0.002 micron can only be obtained in a well regulated instrument under especially favorable conditions. For industrial purposes, the resolving power required is rarely less than 0.005 micron and is frequently determined not by the optics of the microscope but by the nature of the object. For example, organic preparations mounted on a collodion backing do not give a resolution better than 0.01 micron, in which case the useful magnification is 10,000 times.

Statistics from photographs taken in the laboratories of the Institute of the Ministry of the Electrical Industry, State Optical Institute, Moscow Power Engineer Institute, and also abroad, showed that the investigations carried out in most cases did not require a magnification of more than 10,000-12,000 times. Only in isolated cases was it necessary to have recourse to higher magnifications. A changeover in experimental work from the 1,000-x magnification of the light microscope to the maximum magnification of the electron microscope for the same object is impractical. The researcher wants to study the image at an intermediate magnification of the order of 10,000 times. It has become necessary to design an electron microscope giving "intermediate" magnifications but which is considerably simpler than the universal electron "super microscopes."

To satisfy this requirement, the Institute of the Ministry of the Electrical Industry has designed the small MEM-50 electron microscope with the following parameters: anode voltage, 35-50 kv; electronic magnification obtainable directly in the microscope, 1,000-16,000 times; anode current, 20-40 microamps.

The high resolving power of the microscope enables the magnification to be further increased four or five times depending on the photographic material used. The size of the photographic plate is 45 x 60 mm; that of the photographic film is 24 x 36 mm. When film is used, up to 25 pictures can be taken without breaking the vacuum in the microscope.

The microscope consists of a stand the size of a normal desk on which the vertical microscope column is placed. The control panel is located in front of the column. The stand contains all of the supply circuits for the microscope and the vacuum system. A ferroresonant voltage stabilizer and a prevacuum pump are located outside the stand. The pump is installed in a separate box on a shock-absorbing mounting and is connected to the microscope by a flexible rubber tube. This isolates the microscope column from the mechanical vibrations of the pump.

The ferroresonant stabilizer sets up a varying magnetic field which may adversely affect the quality of the image. It is therefore installed some distance from the microscope.

Microscope Column

The column consists of four basic elements: the gun, condenser lens, focusing control with objective chamber, and the photocamera. Because of the special coupling design between separate units, the column of the microscope can be assembled and disassembled in only a few minutes.

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The microscope gun is located underneath and the photocamera on top, which arrangement was found suitable for a small microscope. The fluorescent screen is at eye level while the control for the microscope gun, the electron beam, and objective movement are at hand level, which facilitates using the microscope in production research. Moreover, particles falling from the objective during investigation do not fall on the aperture diaphragm. The diaphragm gets dirty less frequently and rarely requires cleaning. The microscope gun, when the column is in this position, is under the lid of the stand, which makes it easy to connect the column to a high voltage supply, and also enables the microscope to be pumped out through the gun. When the pressure drops in the column of the microscope, a comparatively higher vacuum is obtained in the gun than in the other parts of the column.

The Gun

The construction of the gun also differs considerably from those fitted to other types of microscopes. In microscopes the anode portion is always grounded, while the cathode and focusing electrode are always under a high potential with respect to ground. In this case, the cathode portion is led outside where it is connected to the high-voltage cable. Such a system requires cumbersome shielding arrangements and even then is not wholly safe from accidents. Moreover, a porcelain or glass insulator is a weak defense against possible X-ray radiation, and supplementary lead-shield protection is therefore required.

A shielded gun is used in the microscope described. It consists of a metal, thin-walled sleeve containing the cathode, focusing electrode, and anode. The high voltage is led directly into the gun by means of an armored high-voltage cable. This system is completely safe, both as regards high voltage and X-ray radiation. In addition, a very compact gun results.

The cathode of the microscope is a V-shaped wolfram wire fixed in a sturdy holder and accurately centered with respect to the focusing electrode. To change the cathode, the upper portion of the column is removed at the place where the gun is connected to the condensing lens, the anode and focusing electrode are taken out, and the old cathode is replaced by a new one. The whole operation, including assembly and disassembly of the column, does not take more than 5 minutes.

Condenser Lens

In a small microscope it is possible to use an "illumination" arrangement without a condenser lens, which would decrease the height of the microscope column by 8 cm. However, the use of a condenser lens enables lower anode currents to be employed. Moreover, the utility of the microscope is increased.

The condenser lens is the usual armored lens. The two handles enable the condenser lens to be adjusted with respect to the column of the microscope.

Focusing Device

The focusing device consist of two lenses, an objective and a projector lens. The pole tips are connected by a common rod, which enables them to be adjusted more accurately and thus increases the resolving power of the microscope.

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To replace or clean the pole tips, the camera is removed and the pole tip block removed by means of a key. A set of projection lens tips provided with the equipment enables a magnification of 1,000 to 16,000 times to be obtained.

The objective chamber, which structurally is part of the body of the objective lens, contains the objective stage which can be moved in a plane perpendicular to the optical axis of the microscope. The specimen can be moved smoothly over an area of 0.5 square meter.

The specimen to be investigated is placed on a grid, or diaphragm, as is usual in electron microscopy. The grid, or diaphragm, is fixed on the objective cartridge and held down by a cap. The cartridge is placed in the holder which is inserted, by means of special guides, into the objective plate through a hole in the chamber wall. This automatically introduces the cartridge into the pole tip working space. The objective aperture is covered by an insert made of rubber packing. The objective can be changed in 3.5 minutes (including pumping).

Camera

The image is observed on a fluorescent screen located in the upper cover of the camera. In this case the image can be observed by several persons. To take photographs, a cassette (with plate) or film adapter is placed in the camera. When this is done, the cassette prevents the electrons from reaching the upper screen. To carry out observations even when the cassette is inserted, there is a second fluorescent screen located in front of the cassette. This screen can be seen through the front window of the camera with the aid of a mirror located inside the camera. The cassette takes one 45 x 60--mm plate. The film adapter takes a roll of film for 25 exposures 24 x 36 mm.

The film can be moved without breaking the vacuum by means of a special knob fitted on the side of the camera lid. To move the film one frame, the knob is turned through one revolution. The knob also has a counter which automatically indicates the number of frames exposed.

Plates are exposed by turning the exposure knob located on the side of the camera. When the knob is turned through 45°, the fluorescent screen is lowered and covers the inspection window of the camera; during this operation the photographic plate remains covered by a special exposure screen. When the knob is turned through another 45°, the exposure screen is uncovered and the plate is exposed to the electrons. This arrangement protects the photographic plate from becoming exposed by spurious light coming through the inspection window and dispersed light from the fluorescent screen. The exposure time depends on the photographic material used and varies between 0.5 to 5 seconds.

Vacuum System

The microscope pumping system consists of one rotary prevacuum pump and two diffusion pumps. The vacuum system is controlled by a stopcock, the handle of which is on the upper cover of the microscope table. The stopcock has four positions. In the first position the microscope is connected to the atmosphere; in the second, to the prevacuum pump; in the third, to the high-vacuum pump; and in the fourth position, the microscope is cut off from the vacuum system.

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The vacuum is checked by a discharge tube fed from a transformer. The tube is included in the vacuum system of the microscope gun and is located below the window in the microscope panel. The vacuum is checked by pressing a button. The disappearance of luminescence ("black vacuum") denotes that a vacuum suitable for operating the microscope has been attained.

It takes 3 minutes to pump out the microscope from atmosphere to a high vacuum. Pumping takes longer when photographic material is present, because of degasification of the emulsion. The degasification time depends on the type of emulsion and quantity of photographic material and takes about 15 to 30 minutes. If degasified film is exposed to the air for a short time (10-20 minutes), it reabsorbs hardly any gas. Pumping out the microscope with degasified film takes the same time as when no film is present. It is therefore recommended that the film be degasified in a separate vacuum apparatus and then inserted in the microscope.

Supply Circuit (designed by Yu. B. Zolotorenko under the supervision of G. F. Zakharov)

The electrical circuit of the microscope consists of the gun supply unit and the lens supply unit.

The gun supply unit provides the high voltage between anode and cathode, the filament voltage of the cathode, and the voltage for the focusing electrode. The high voltage is supplied from a selenium or kenotron rectifier and is regulated in steps -- 35, 40, 45, and 50 kv. The necessary stabilization is ensured by a special electronic stabilizer. The filament supply is from a 220/5-volt step-down transformer, whose secondary winding is insulated from the primary and ground for the full anode voltage.

The lens supply unit feeds regulated voltage to the objective, condenser, and projector lenses. The voltage is supplied from a rectifier using current stabilization.

In addition to individual electronic stabilizers, all the rectifiers are fed from a common ferroresonant stabilizer connected to the 220-volt line. The microscope works satisfactorily when the line voltage varies plus or minus ten percent.

All the controls of the microscope supply system are concentrated on the control panel.

Use of the Microscope

The microscope can be used in all fields where the investigator requires a useful magnification of the order of some tens of thousands, such as biology, metallography, powder metallurgy, chemistry, materials study, etc.

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